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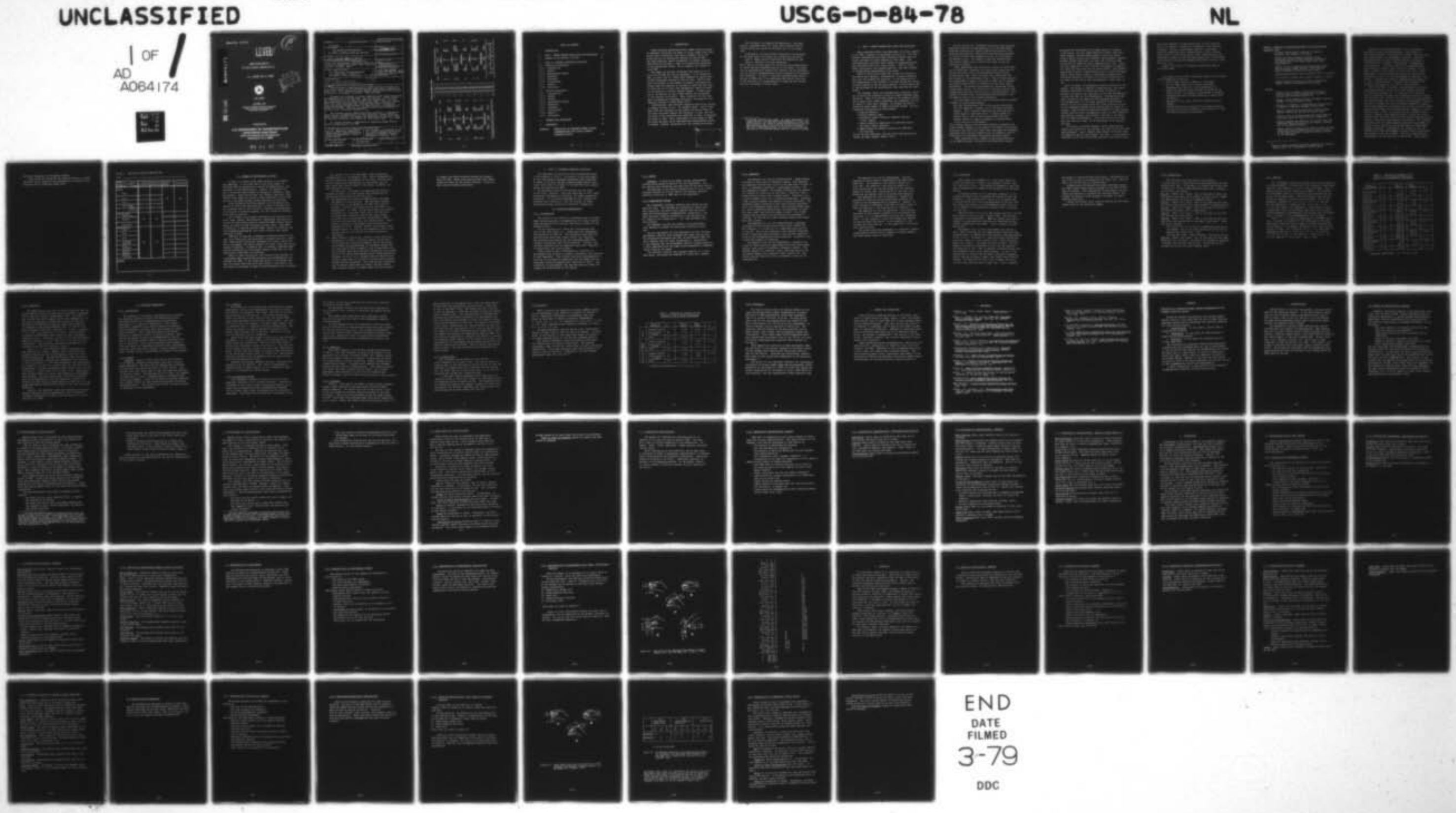

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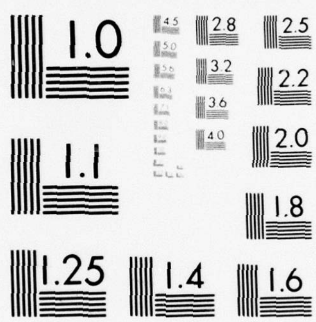

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K.H.E. KROEMER AND W.S. MARRAS

FINAL REPORT

SEPTEMBER 1978

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16. Abstract

Visual Distress Signaling Devices (VDSD) should be designed for safe and efficient use by untrained boaters under adverse operational conditions. Thus, Ergonomics/Human Factors information should be used intensively to optimize the boater - VDSD interface.

Research was performed to assess compliance with Human Engineering recommendations in existing VDSD. For this purpose, a field survey was conducted first, in which the VDSD were categorized. Critical Ergonomics/Human Factors aspects were established. Secondly, laboratory tests were performed that indicated the effects of selected Human Engineering design features on identification, unpackaging, and operation of VDSD. Finally, the research results were validated in (realistically simulated) emergencies.

The research results demonstrated that adherance to Ergonomics/Human Factors recommendations is often missing in present VDSD, but would greatly increase the chances for successful activation of VDSD by untrained operators, and reduce the time needed (here: up to 80%).

The report contains a compilation of Ergonomics/Human Factors design recommendations for VDSD.

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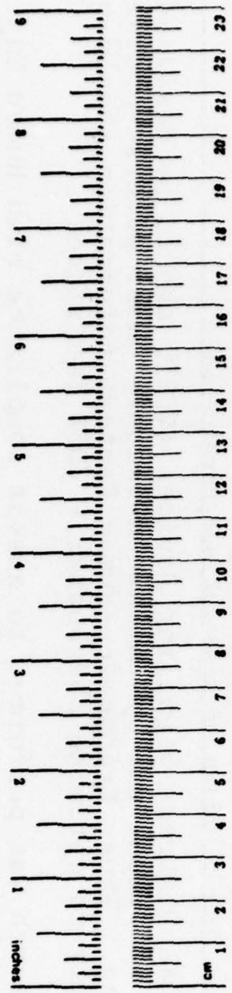
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

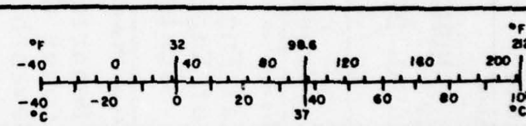
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

Visual Distress Signaling Devices (VDSD) used by boaters in emergency situations are meant to notify others that there exists such a situation, that help is needed, and to aid search parties in locating the persons in need of help. For these purposes, easily recognized, and easily operated VDSD should be available. This is of particular importance to the recreational boater, who is normally not trained in using VDSD.

The number of distress situations that would or do require use of VDSD can only be estimated. It is indicative that, in 1973, the U.S. Coast Guard expected to assist about 35,000 recreational boatmen in need of help. Hand in hand with the increase in the number of boaters, the search and rescue cases are expected to increase by about 6% every year. In about one out of every four emergencies, people on board are in moderate to serious personal danger. In many cases, use of (or failure to use) a VDSD affects the seriousness of the situation critically. Thus, simplicity of use, and ease in reading and following directions, are among the most important features of VDSD (Miles 1977).

Unfortunately, many distress signaling devices are lacking in design for ease of use. For example, McHale (1977) found that (with the exception of one brand) the plastic bags of the flare and smoke signals were difficult to open, and that the print of the directions was difficult to read, or obscured by sealer or tape. Thus, improvement of the design of VDSD for quick and easy use by untrained and inexperienced boaters in needed. However, guidelines for such design are missing.

The following text reports the experiments, and their results, performed under U.S. Coast Guard contract DOT-CG-72225-A during the period of 16 August 1977 to 31 October 1978.

According to the plan of work contained in the proposal to the Coast Guard, the effort was divided into two parts:

Task I, Human Factors[1] Field Test and Evaluation, and

Task II, Distress Situation Validation.

Task I had as its main goals the collection and categorization of Visual Distress Signaling Devices on the market, the selection of representative samples for research, and the determination of critical ergonomic/human factors aspects in the operator-VDSD interface. In Task II, specific ergonomic/human factors aspects of VDSD were to be established and tested, resulting in the validation of recommendations of human factors principles for the design of future VDSD.

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[1] Following international usage, the terms "Ergonomics" and "Human Factors" are employed interchangeably in this text. Both indicate "the study of human characteristics for the appropriate design of the work and living environment". The term "Human Engineering" is prefered to indicate the application of Ergonomics/Human Factors research findings.

2. TASK I, HUMAN FACTORS FIELD TESTS AND EVALUATION

Every reasonable effort was undertaken to collect samples of all VDSD currently on the market in the U.S.A. For this purpose, manufacturers and major wholesale dealers were contacted and asked to supply samples of their VDSD. Also, catalogues were consulted, and a number of signaling devices were purchased from local retail dealers. The U.S. Coast Guard, particularly the research monitors, were most helpful in accomplishing completeness of the survey.

While no claim can be made that in fact all devices on the market were obtained, circumstantial evidence indicates that very few escaped the attention. As an indication for the completeness it may suffice to say that during the second six month period of the one year contract, no new devices came to the knowledge of the experimenters that they had not seen before.

All together, about 150 specimens were collected, almost all of which were produced by about one dozen different manufacturers. Many of the devices seemed to be primarily different in their color scheme, packaging, and trademarks, but not to differ in their basic designs. An attempt was made to divide the great number of VDSDs into major groups. The following main categories were established:

* flag and pennants
* battery powered lights
* continuous lights created by chemical reaction ("cool" lights)
* lights created by combustion (a) hand-held flares, (b) aerial flares (meteors)
* smoke created by chemical reaction (a) hand-held, (b) floating

By far the most important, and most often used devices are flares and smoke signals (Miles 1977).

Initial discussions, literature indications and anecdotal experiences relayed by experienced boaters and Coast Guard personnel indicated that certain VDSD posed relatively few human factors problems, while others were much more critical in terms of either their frequency of use, or the problems encountered in use. For example, flags and pennants were used rather seldom, and if used did not seem to pose any significant problems.

These impressions were tested in a series of field tests, most of which were conducted in a public boat access area to the Detroit River, within the metropolitan Detroit area. During several days, about 20 people were interviewed and participated in the preliminary tests. None of these sessions were preplanned or highly structured in order not to exclude any factors which should be considered in the later formal experiments. The persons interviewed and tested were either recreational boaters, or operators of a delivery service that relayed goods and mail from the shore to passing ships. Also, another 20 persons were interviewed and participated in the preliminary tests in the authors' laboratory.

The interviews and field tests with these persons yielded a number of interesting findings:

> Very few (approximately 5%) of the persons interviewed had ever operated, on board, any of the marine distress signals. Only 2 persons indicated that they had used a smoke signal or hand-held flare. A larger number of persons (about 10%) of these interviewed, had used highway flares to signal an emergency situation while on the road with an automobile.

This finding supports many previous anecdotal statements and gives further credence to the concept that boaters in distress situations (for which they should have knowledge and preferably experience with distress signals) must be assumed to have no knowledge of, or experience with, marine distress signals.

When confronted with a random or semi-random selection of the VDSD available, the people interviewed were usually

surprised and confounded by the large variety of devices. In particular, the most common hand-held flares, hand-held smoke signals, floating smoke signals, and aerial flares usually caused surprise and confusion when presented together, because neither their form, nor size, nor coloring scheme would give any immediate clues regarding type or use. About the only exceptions to that rule are flashlights or pennants, the later only when taken out of their pouches. The subjects, when asked to select a named device such as a hand-held smoke signal, would usually resort to grasping at random devices from those displayed, and then try to find an indication on the label of that device they had happened to take, what it was.

After the phase of displaying an array of devices to the subject and asking to identify a specified one, the subject generally was given one device and asked to operate it. Usually, the subject was surprised to find that the manipulation was not easy nor self-explanatory. Problems arose generally either in the removal of the packaging material or, this accomplished, in the actual operation of the device. Removal of the protective covers was often difficult because of the resistance offered by the plastic bags or covers to tearing. Some protective boxes were difficult to open because openers were not easily recognized as such, or their operation was difficult because, for instance, they had to be pushed with two hands simutaneously. The proper direction of movement was often not clear, or the resistance to be overcome was high.

On account of possible hazards, actual operation was usually not carried out all the way, but only the initial steps were performed. Again, subjects were amazed by the fact that the operation was not self-evident, nor easy. It was generally necessary to use the instructions printed on the device which

were often difficult to read (black print on dark red background, for example), difficult to understand, and difficult to follow. Subjects twisted when supposed to turn caps, pulled in wrong directions, looked straight into the nozzle when trying to shoot off an aerial flare, scratched with the fingernail instead of using the appropriate piece of the device, tried to shoot through the packaging enclosure, could not twist off a cap, etc.

Table 1 lists some of incidental observations made in the survey phase.

The results of this first orientation phase of the research can be summarized as follows:

* A very large variety of VDSD is on the market.
* Most of these VDSD are not easily identified regarding their function or use characteristics.
* Protective material often obscures the label or the device itself, thus making it even harder to identify.
* Packaging material is often difficult to remove from the device.
* Operation of the device itself is usually not self-evident.
* Printed instruction, necessary for correct operation of most of the existing devices, are difficult to read and often difficult to understand.

TABLE 1: Examples of Observations Made in the Survey Phase

EXCESSIVE TIME

- It takes subject about 2 minutes to identify, unpackage, and operate a red flare.
- Subject has great problem in opening a box containing an aerial flare launcher, because the two latches have to be moved toward each other simultaneously.
- Subject trying to identify hand-held smoke signal from an array of VDSD, selects 7 other devices until he happens to grasp the smoke signal.
- Eleven wrong attempts until projective flare is selected.
- Six incorrect choices until signal launcher is found.
- Subject breaks off latch (and almost injures his finger) from box containing flare launcher.

FAILURE

- Subject tries to operate red flare by biting (!) into the device and by striking the scratching surface with the removed paper top.
- Subject, after numerous incorrect attempts, gives up attempt to select parachute flare.
- Subject is incapable to understand the instructions to operate a specially packaged aerial flare.
- Subject cannot read instructions on flare because they are covered by the end of the pull tape.
- Subject tries to activate hand-held smoke signal by scratching ignition surface with his thumb nail.
- Several subjects are unable to rip plastic bag from hand-held flares and use teeth to achieve a starter cut in the plastic material.
- Subject fails to deploy aerial falre on first attempt, then points nozzle towards his face while pulling on the chain in order to observe success or failure of the deployment.

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[2] Many of these occurances have been preserved on videotape, usually with 2 or 3 simultaneous viewing angles.

Based on the experiences made in the survey phase, a preliminary rating form was developed. (See Figure 1.) This form establishes the categories "coding", "instructions", and "manipulation", as independent variables. These are associated with the steps "identification of function", "identification of (proper) manipulation", "unpackaging", and "operation". Obviously, some of the independent variables apply to certain steps, but not to others. For example, "coding" (with respect to form, size, color, label) does apply to the identification of both the function and manipulation, but not to the unpackaging or operation. Conversely, "instructions" apply to unpackaging and operation but not to identification. "Manipulation" applies to unpackaging and operation, but not to identification.

Each of the VDSD available, and significantly different from related models, was rated by three primary researchers using this rating form. A scale of 1 to 10 was used, with 10 indicating the best and 1 indicating the worst rating for the given item. Owing to the fact that only three persons rated the devices, that the rating scale was somewhat "floating", and that no attempt was made to establish completely independent ratings among the researchers, the results of these ratings cannot be considered as being quantitative, complete, or fully substantiated. (Thus, the results are not included in this report.) However, this approach helped to point out certain problem areas, and other areas with no obvious difficulties with respect to the human engineering of the devices. For instance, hand-held flares or smoke signals displayed a large number of serious faults, while battery powered hand-held flashlights showed no problems. Furthermore, the attempt to rate the devices led to the establishment of three clearly distinquishable phases in the use of VDSDs. These are identification, unpackaging, and the operation of the device. These phases

were used throughout the following research.

Thus, while the rating was not pursued further, it served very well in the course of the investigation to pinpoint problem areas and to categorize usage steps.

FIGURE 1: PRELIMINARY RATING FORM FOR VDSD

Item: ______________________________

Indep. Variables \ Steps	Identification of: Function	Identification of: Manipulation	Unpackaging	Operation
CODING Form				
Size			NA	NA
Color				
Label Name/Symbol				
Location				
INSTRUCTIONS Legibility				
Content	NA	NA		
Locations				
MANIPULATION Form				
Size				
Grip				
Strength Required	NA	NA		
Tools Required				
One/Two Handed				
Motions Involved				
REMARKS				

2.1 Summary of the Results of Task I

In Task I, a survey of the VDSD currently on the market was completed. It was found that a very large number of different VDSD is produced by a variety of manufacturers, and available to the boating public. However, the devices fall into a relatively small number of categories, primarily, flags and pennants, light sources from cool chemical reactions, light sources from combustion (flares, either hand-held or fired into the air), and smoke signals (either hand-held or floating).

Field evaluation involving subjects and discussions with experts in this field indicated that it cannot be assumed that the potential user of such a device is familiar with appearance or activation of distress signals, but that he/she has probably never seen or used one.

Use of VDSD can be divided conveniently and logically into three steps, namely; identification, unpackaging, and operation. In each of these phases specific ergonomic/human factors aspects apply, but have not been considered in many cases. This makes it difficult to identify specific VDSD, results in difficult and time-comsuming unpackaging, and causes difficult and lengthy operation of VDSD.

VDSD must be employed in emergency situations which put the user into a physically and emotionally stressful position. Therefore, VDSD should be purposely designed to be easily identified, easily unpackaged, and easily operated for quick, safe, and correct distress signaling. It appears that, at present, ergonomic/human factors principles for the suitable design of VDSD have not been sufficiently identified, nor employed.

Based of these conclusions, the literature was searched for established human engineering principles and recommendations applicable for VDSD. It was found that many of the problems existant in current VDSD could have been avoided, often easily, had the wealth of knowledge in human factors/ergonomics been considered.

The appendix lists, for each phase, human engineering recommendations for the design of VDSD. These recommendations have been extracted, and modified if necessary, from military sources (where Human Engineering has been widely used for many years) and research results, text books, standards, etc. (See reference section.)

In collecting, evaluating, and compiling the material suitable for VDSD, it became obvious that information was insufficiently available in only two areas:

(a) The principles and details of shape coding, including the aspects of form and size. The only major reseach in this area was performed in the 1950's for aircraft controls. However, the results are not applicable, or transferrable, to VDSD. On the other hand, the research performed (e.g. by Bradley 1956, Ely at al 1956, Hunt and Craig 1953) indicates clearly that shape coding principles can be developed that significantly reduce selection and operation time, and related errors. Hence, similar reseach and development should and could be performed for VDSD. However, conduct of such work, while probably within the scope of the statement of work of the current contract, was outside the time and monetary limitations.

(b) Human strength capabilities, related to force and torque requirements of VDSD. A critical survey, particularly of the applicable military standards, and of the authoritative Human Engineering Guide for Equipment Design (Van Cott and Kinkade 1972) revealed a lack of applicable data. The principal researcher even went through the old research files of the former Anthropology Branch, Human Engineering Division, of the U.S.A.F. Aerospace Medical Research Laboratory, where much of the work on related human strength studies had been performed. Only some sketchy information was discovered, which does not supply the data needed. Thus, related research on human finger and hand strength

is needed, and would certainly provide the missing data for VDSD. While such research might have fallen within the scope of the current contract, it was outside time and funding limitations.

3. TASK II, DISTRESS SITUATION VALIDATION

The experiments in Task II of this research were based on the findings of Task I. In contrast to the first phase, in this task formally designed experiments were performed in order to evaluate selected ergonomic/human factors principles which would be helpful in the identification, unpackaging, and operation of VDSD.

The research in Task II was divided into two steps. In the first, laboratory tests were performed to test, under controlled environmental conditions, key human engineering principles. In the second experimental step, on-water experiments were conducted to test the validity of human engineering design features in "realistic" emergencies.

3.1 Laboratory Experiments

3.1.1 Introduction

The purpose of the laboratory experiments was to validate human factors/ergonomics recommendations for Visual Distress Signaling Devices which had been identified in Task I of the research effort.

Two key variables were chosen for investigation from each of the three steps (i.e., identification, unpackaging, and operation) of VDSD use. The variables chosen from the identification phase were "shape coding" and "labeling". The variables investigated for the unpackaging phase were "wrapper utilization" and "latch operation". Finally, the variables employed from the operation phase were "legibility of instruciton" and "color coding".

These variables were investigated as a function of performance time required to achieve successfully the objective of each experiment. Each variable was also investigated as a function of the degree of compliance with the human factors/ergonomics design recommendations identified in Task I. The variability of performance time was then used as a basis for judging the effectiveness of the design.

3.1.2 Method

Subjects - 15 male and 15 female college undergraduate students participated as subjects for this experiment. All the subjects were volunteers and were paid $15 for their efforts. The mean age of the subject population was 22.33 yrs. with a standard deviation of 2.02 yr. None of the subjects reported familiarity with any of VDSD used in the experiments.

3.1.3 Experimental Design

Two independent variables (stimuli) were chosen for each operation step. Each variable was divided into three treatment conditions, one which fully complied with the prosed human factors/ergonomics recommendations (condition 1), one which partially complied (condition 2), and one which did not comply at all (condition 3). All other variables were held constant.

The dependent variable was defined as the performance time required to achieve the particular objective of each test.

The null hypothesis for this experiment was that the mean performance times for each treatment were equal ($pt_1=pt_2=pt_3$). The alternative hypothesis was that the performance times for each treatment were not equal ($pt_1 \neq pt_2 \neq pt_3$). Specifically, it was expected that the performance time for testing condition 1 (full compliance with the human factors/ergonomics recommendations) would be the lowest.

Ten different subjects were assigned randomly to a treatment group; each group was composed of 5 males and 5 females.

3.1.4 Apparatus

The apparatus for test #1 (Identification - Shape Coding) consisted of three types of hand-held flares. Each specimen was completely covered with a coat of the same dark red paint in order to eliminate coloring as a confounding variable. For the independent variable, the primary stimulus was the presence (or absence) of a hand grip on the flare. Condition 1 was a common hand-held flare with a shaped handle. Condition 2 was a regular highway fuse with a cylindrical hand grip. Condition 3 was a regular highway fuse without a distinct hand grip. The secondary stimuli consisted of five other devices (parachute flare, self-contained aerial flare, self-contained smoke canister, and a combination smoke/flare), all dissimilar in shape from each other, and from the primary stimuli. All stimuli (primary and secondary) were painted red and contained no labeling. In this way all other variables except form coding were held constant.

The apparatus for test #2 (Identification - Labeling) consisted of three orange plastic boxes (about 20x10x5 cm). For condition 1, a silhouette of a signaling pistol was put on the lid. The box for condition 2 was lettered "signaling pistol" (lettering done according to the relevant specifications of the recommendations in the appendix). Condition 3 was a plain box without any labeling.

The apparatus for test #3 (Unpackaging - Wrappers) consisted of three identical common hand-held flares with wooden handles, each sealed in identical transparent plastic. The plastic wrapper for condition 1 had a self-starting pull tab. The pastic wrapper for condition 2 had a starter cut. The plastic bag of condition 3 was not prepared to have any unpackaging aid.

The apparatus for test #4 (Unpackaging - Latches) consisted of three boxes of approximately the same volume (6000 cm^3). The condition 1 box could be opened via a "lift tab", the condition 2 box could be opeded via a self-starting pull tab, and the condition 3 box could be opened via "cross tabs" (requiring one of the tabs to be pushed and the adjacent one to be pulled simultaneously).

The apparatus for test #5 (Operation - Legibility) consisted of identical instructions whose lettering conformed to the recommendations in Appendix A. However, the color contrast in condition 1 was white on black, black on white in condition 2, and black on red in condition 3.

The apparatus for test #6 (Operation - Color Coding) consisted of three wooden sylinders of 2.5cm diameter and 25cm long, i.e., of approximately the size the a hand-held flare. In the condition 1, half the cylinder was painted red and the other half white. In the condition 2, the cylinder was brown and red. In the condition 3, the colors were black and blue.

The actual tests were performed in a laboratory chamber (approximately 6x4x3m) with no windows, in which lighting and noise levels could be controlled.

3.1.5 Procedure

Each subject was assigned to a trial order which contained two condition 1 trials, two condition 2 trials, and two condition 3 trials. The conditions assigned to each test were counterbalanced to minimize the possibility of carryover effects.

To achieve resemblence to a distress situation, a low illumination/high noise environment was created in the test laboratory. The lighting level was at 0.01 ft.Lambert and a constant 80 dB white noise was maintained in the test room. The subject was exposed to a pre-adaptation light level of .24 ft.Lambert for approximately 1 minute prior to entering the test room.

When the subject arrived in the testing area he or she was first asked to read and sign a consent form. The form was witnessed by the experimenter. Then the subject was asked to respond to a questionnaire which gave an indication of the subject's familiarity with VDSD , state of health, and preferred hand.

The subject then entered a pre-chamber and stood at a line. While receiving the test instructions (read from standardized texts, see Section 3.1.6), the subject's eyes pre-adapted to the .24 ft.L. illumination. Then the subject entered the test room, stood on a line, facing a wall. When the experimenter said "begin", the subject started the test. The time needed to achieve the objective of each test was measured. The objective of test 1 was to identify a hand-held flare from the secondary stimuli (five other devices). In test 2 the subject was to identify the box which contained a signaling pistol from the secondary stimuli (two similar boxes with no coding). The objective of test 3 was to unwrap the device. In test 4 the objective was to open a box. Test 5 required

the subject to follow written instructions. The objective of test 6 was to pick up a cylinder by the "safe" end. (See section 3.1.6 for the texts of instructions.)

Between tests the subjects were given unrelated secondary tasks (elbow flexion muscle strength tests) which lasted about 10 minutes. This interruption of the primary test procedure was expected to dissipate any ordering effects, and allowed the subjects' visual systems to re-adapt to normal lighting conditions

During the primary tests, only one subject and one experimenter were in the laboratory chamber.

3.1.6 Instructions

The following texts were read to each subject. "I would like you to enter this room and stand facing the wall opposite this door. On the wall is a black X and on the floor a black line. Please stand behind the black line, looking at the X until I say 'begin'."

Test #1. "When I say 'begin', turn to the table on your left, and based on the shape of the objects in front on you, choose the device which you think is a hand-held flare."

Test #2. "When I say 'begin', turn to the table on your left and pick up the box which you think contains a signaling pistol."

Test #3. "When I say 'begin', turn to the table on you left and unwrap the device that is lying there."

Test #4. "When I say 'begin', turn to the table on your left and open the box lying there."

Test #5. "When I say 'begin', turn to the table on your left and follow the instructions on the paper lying there." Their text was as follows:

> "The pistol in front of you is a signaling pistol and is not loaded. Turn to the table behind you and follow the instructions lying there." and
>
> "Pick up the pistol. Aim at ceiling. Put pistol in box."

Test #6. "When I say 'begin', turn to the table on your right. There will be a cylinder. One end of the cylinder is dangerous to handle, and the other end is safe. Please pick up the cylinder by the end you would consider safe."

3.1.7 Results

The performance times were analyzed via a one-way analysis of variance (ANOVA). For each test, the variances of performance times for each condition (1,2 and 3) were considered. Table 2 presents results of the testing in six ANOVAs. The treatment (of conditions) refers to the quantity which measures the variation of the sample means. The error measures the variation within the samples of the six tests performed. Test #4 (Unpackaging - Latches) ($F = 15.17$, d.f. = 2.27, $p \leq .05$) and Test #5 (Operations - Legibility) ($F = 6.29$, d.f. = 2.27, $p \leq .05$) were found to be significant. These results reflect a significant effect of the design compliance with the human factors/ergonomics recommendations and indicate that performance time is reduced when the recommendations are followed.

Tests 1, 2, 3, 6 were not significant in the ANOVA evaluation. In order to determine if the differences in the mean performance times were due to chance or whether they were due to the effects of the designs, conditions 1 and 3 were evaluated via a t-test. The t-test for tests 1, 2, 3, and 6 were all significant (Test #1 $t = 6.59$, d.f. = 18, $p \leq .01$; Test #2 $t = 8.87$, d.f. = 18, $p \leq .01$; Test #3 $t = 20.62$, d.f. = 18, $p \leq .01$; Test #6 $t = 12.12$, d.f. = 18, $p \leq .01$).

TABLE 2: ANALYSIS OF VARIANCE OF THE RESULTS OF THE LABORATORY EXPERIMENTS

	Sourse of Variation	d.f.	Sum of Squares	Mean Squares	F
Test #1	Treatments	2	17.69	8.85	0.38
	Error	27	633.84	23.48	
	Total	29	651.53		
Test #2	Treatments	2	6.09	3.04	0.53
	Error	27	153.63	5.69	
	Total	29	159.72		
Test #3	Treatments	2	1800.57	900.28	2.55
	Error	27	9532.03	353.04	
	Total	29	11332.60		
Test #4	Treatments	2	1512.75	756.37	15.17*
	Error	27	1346.10	49.85	
	Total	29	2858.85		
Test #5	Treatments	2	5902.99	2951.49	6.29*
	Error	27	12657.84	468.81	
	Total	29	18560.83		
Test #6	Treatments	2	6.68	3.34	0.83
	Error	27	108.87	4.03	
	Total	29	115.55		

* Indicates significance, i.e., $F \geq F_{.05} = 3.39$.

3.1.8 Discussion

The ANOVA analysis for Tests #4 and #5 indicates that the design compliance with the human factors/ergonomics recommendation is directly related to performance time. The trend is that the more the device complies with the recommendation, the less time is required to achieve the objective of the test. The effects of performance time with regulation compliance is reflected in the mean performance time. In test #4, the mean performance times were: condition 1 - 5.9 sec., condition 2 - 23.2 sec., and condition 3 - 12.9 sec. This represents a decrease in performance time required of over 75% between condition 1 and 2. Similarly, in Test #5, the mean performance times for condition 1, 2 and 3 were 21.7, 33.6, and 55.6 sec. respectively. This reflects a decrease in performance time required of over 60% for condition 1 from 3.

Tests 1, 2, 3, and 6 exhibited similar characteristics when analyzed via t-tests. However, here, only conditions 1 (complete compliance) were tested against conditions 3 (complete noncompliance). The mean performance times for Tests 2, 3, and 6 also exhibit reduced time requirements for condition 1 than for condition 3. The mean performance time requirements for condition 1 of tests 2, 3, and 6 were 3.8, 18.9 and 3.8 sec. respectively. The mean performance times required for condition 3 of tests 2, 3, and 6 were 4.8, 37.9 and 5.0 sec. respectively. Each of these exhibits at least a 20% reduction in performance time required. One can conclude that if the device complied with the recommendations, the time required to achieve the objective of each test was significantly less than was the time needed with devices which did not comply at all with the recommendations.

Overall, this experiment shows that compliance with human factors/ergonomics design recommendation for the individual variables (independent variables) aids significantly in quick operation of a VDSD.

3.2 On Water- Experiments

3.2.1 Introduction

The purpose of the on-water experiments was to validate key ergonomics design principles for VDSD which had been identified earlier (via recommendations and laboratory experiments), in (simulated) emergencies. The on-water experiments culminated the previous research by combining several independent variables which were previously investigated separately. Thus, these experiments investigated additive or synergetic effects of several variables, representing the manner in which the recommendations could be used in the actual design of VDSD to optimize efficiency and ease of operation. The on-water experiments were unique in that they tested the independent variables under environmental conditions which were quite similar to actual emergency situations, however, without jeopardizing the safety of the subjects.

3.2.2 Method

Subjects - Twenty subjects (who had not participated in the earlier laboratory experiments) took part in the on-water experiment. Ten males and ten females were volunteers and were paid five dollars per hour for their efforts. All subjects were over twelve years of age (the legal age required to operate a craft). The mean age was 23.56 years, the standard deviation was 5.5 years. Eighteen subjects considered themselves good swimmers. Three of the subjects reported experience with highway flares, but none reported experience with marine signaling devices. The subjects did not know the exact purpose or hypotheses of the experiments.

3.2.3 Stimuli

The stimuli for the primary tasks consisted of two wooden VDSD models. Device A was approximately the size of a hand-held flare (2.5cm diameter, 25cm long). One half of the device was cylindrical and painted red. Its end was covered by a rubber cap (similar to the "ignition cap" with actual VDSD) under which sand paper acted as the scratch surface. The other half of the device was shaped to the hand (shape coding, like in laboratory test 1, condition 1) and was painted white. The device was sealed in a plastic bag which contained a self-starter tape (sealing a cut in the bag), similar to the tape used in laboratory test #3, condition 1.

Device B was the same length as device A but was cylindrical throughout, i.e., it had no shape cue for hand operation. The entire device was painted red. One end of the device had an ignition cap and scratch surface like device A. The other end of the device contained a similar cap with a pull chain underneath. Device B was also sealed in a plastic bag (like device A) but had no self-starter tape, or starter cut. Both devices looked so realistic that the subjects were not aware of the fact that the devices were inert.

Although both devices appeared realistic, they were also designed to be non-specific. The could be interpreted as hand-held flare or smoke signals, or as a combination flare-smoke, or as launchers for aerial flares.

3.2.4 Experimental Design

The independent variables (devices A and B) for this experiment consisted of two testing conditions. Condition A (treatment A) was a device which incorporated several of the human factors/ergonomics design recommendations combined (color coding, shape coding, packaging) from the laboratory experiment. The device used in condition B (treatment B) did

not exhibit any of these qualities but represented conditions which exist in many VDSD.

The dependent variables in this experiment consisted of the performace times required to unpackage and operate devices A and B.

Each subject was tested under both conditions A and B with sex and presentation order of the independent variables counter-balanced.

The null hypothesis for this experiment stated that there were no difficulties in unpackaging and operation times required for devices A and B ($pt_A = pt_B$). The alternative hypothesis stated that devices A and B required different activation times ($pt_A \neq pt_B$), specifically that the device which incorporated human factors/ergonomics design recommendations required less time.

3.2.5 Apparatus

The stimuli (devices A and B) have already been described in detail. The other equipment utilized in the conduct of the experiment was a two-man inflatable rubber raft (subject vessel) which was rigged to deflate as desired. A motor boat was used for transportation, subject observation, timing, filming and as standby rescue vessel. Clipboards with elapsed time increment stopwatches were used for timing purposes. Coast Guard approved life vests were used to ensure subject safety. All on-water experiments were performed in a bay off Lake Sherwood near Milford, Michigan, where two small islands served as "base stations".

3.2.6 Procedure

Initially, each subject was asked to read and sign standard consent forms, approved by the Wayne State University Human Subject Committee. The subject was then driven by boat to one of the two islands in the lake selected according to the wind conditions. (All tests were performed during the summer months of 1978. Tests were only performed when there was no significant rain or wind.) There, the subject read the instructions (see 3.2.)

which indicated the assignment was to rate the effectiveness of VDSD which the experimenter would be using. (This was, in fact, a secondary task.) The subject was also told that in case of emergency, a VDSD was provided on board the subject vessel (primary task). The subjects were not informed that watching and rating VDSD activated by the experimenter was only a secondary task designed to divert the subject's attention from the deflating of the raft. The subject then donned a life jacket, boarded the raft, and was pushed out into the lake with the raft attached by a 50 ft. rope to the motor boat or a stake on an island (depending on the conditions). While the subject was watching the experimenter handle a VDSD, the raft deflated automatically, prompting the subject to activate the emergency signal (device A or B) placed in the raft. The time required for unpackaging and successful operation of the subject's devices was recorded. Then the subject was pulled back to safety. The same procedure was followed with the second device.

3.2.7 Instructions

The following text was given to each subject:
"Your assignment is to board a raft. You will be towed to a selected spot on the lake where we would like you to rate the visibility of signals which we on the boat will be setting off. We would like you to rate these from 1 to 10, with 10 being the best rating and 1 being the worst."

"In the event that an emergency occurs upon your raft (taking on water or deflation), signal the experimenters with the signaling device on board the raft. The signaling device is activated by opening the package, holding the device with one hand by the safe end, removing a cap from the other end, and striking the scratch surface with the cap."

3.2.8 Results

Table 3 presents the Analysis of Variance (ANOVA) results for the performance times needed for activation of devices A and B. Significant differences in performance times were found for each phase of device utilization (Unpackaging: $F = 31.26$, d.f. = 1, $p \leq .01$; Operation: $F = 12.5$, d.f. = 1 & 19, $p \leq .01$; Total (unpackaging and operation combined): $F = 60.0$, d.f. = 1 & 19, $p \leq .01$).

The mean performance time for device A was 0.289 minutes whereas the mean time for device B was 1.376 minutes. In other words, on the average it took almost 400% longer to activate the badly designed device B than the well designed device A.

The longest performance times for devices A and B were 0.67 minutes and 2.53 minutes respectively. The shortest performance times for devices A and B were 0.10 and 0.36 minutes respectively. This range represents much less variability for device A than for device B, in addition to the much shorter performance times for A than for B.

TABLE 3: ANALYSIS OF VARIANCE OF THE RESULTS OF THE ON-WATER EXPERIMENTS

	Source of Variation	d.f.	Sum of Squares	Mean Square	F
Total	Between Groups	1	14.82	14.82	60.00*
	Error Within Groups	38	9.40	0.25	
	Total	39	24.22		
Unpackaging	Between Groups	1	5.94	5.94	31.26*
	Error Within Groups	38	7.22	0.19	
	Total	39	13.16		
Operation	Between Groups	1	1.00	1.00	12.50*
	Error Between Groups	38	3.14	0.08	
	Total	39	4.14		

* Indicates significance, i.e. $F \geq F_{.01} = 7.31$

3.2.9 Discussion

The results indicate that the additive effects of the human factors/ergonomics design recommendation variables applied to a VDSD significantly reduce mean performance time in an on-water distress situation. The mean performance time for the unpackaging period was reduced by 83% when a self-starter was used as an aid for unpackaging, instead of having a plastic bag with no starter aid. The operation time was reduced by 70% when qualities such as shape coding, color coding, and non-ambiguous design were incorporated. These simple human factors/ergonomics measures reduced mean performance time by over 78% for the total activation (unpackaging and operation times combined) of the device.

These significant reductions in mean performance times are due solely to the physical features of the device itself and the package since labeling and instructions were not used for the devices. (Labeling and instructions, however, were found to show significant differences in the laboratory experiment.)

The results of this experiment indicate that simultaneous utilization of several simple human factors/ergonomics recommendations in the design of a VDSD will evoke the logical and natural expectations of the manner in which a VDSD should be used correctly, and thus significantly reduce operation time.

4. SUMMARY AND CONCLUSIONS

Visual Distress Signaling Devices, on the market today, come in a large variety of types, shapes, colors, and wrappers. Unfortunately, most of these VDSD fail to meet ergonomic/human factors design principles. Thus, most devices are difficult to identify, to unpackage, and to operate even under non-emergency or laboratory conditions. Adherence to ergonomics/human factors principles would make the use of VDSD much simpler, easier, and quicker in emergencies. The results of the field survey, laboratory research, and on-water experiments clearly support this conclusion.

Human engineering design recommendations, applying to the identification, unpackaging, and operation steps, have been compiled for VDSD. Adherence to these recommendations would, in most cases, not require major re-design efforts. Thus, with relatively small outlay, significant improvements in the useability of VDSD can be achieved, resulting in higher safety and efficiency of the boater-distress signal interaction.

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APPENDIX

COMPILATION OF ERGONOMICS/HUMAN FACTORS RECOMMENDATIONS FOR DISTRESS SIGNALING DEVICES

During the research stipulated by the U.S.Coast Guard contract 72225-A it was found that the use of Visual Distress Signaling Devices may be conveniently and logically separated into three distinct phases;

1. Identification. In this phase a certain VDSD is recognized and selected.
2. Unpackaging. In this phase the VDSD selected is freed from enclosing material.
3. Operation. In this phase the activation and use of VDSD takes place.

The following text enumerates human factors/ergonomics considerations and recommendations for each of these phases. It will be noticed that some of the recommendations are unique and apply only to a given phase, or even to a given state within this phase, while others are identical or nearly so for several phases. However, it was felt that they should be given for each of the phases separately so that each section of the recommendations can be used independently.

A short introduction to each section of this listing of recommendations identifies the main problem areas.

1. IDENTIFICATION

Identification is the first and possibly the most crucial phase in the signaling sequence. In the identification phase, the user must determine quickly and accurately what type of VDSD to select, what it will do, and how it is to be handled. The human factors/ergonomics means used to facilitate identification are commonly called "coding".

The evaluation of existing VDSD indicated that serious problems exist with respect to identification. When subjects were told to select from an array of VDSD a specific one (for instance a hand-held smoke signal), they often found it difficult and time-consuming to find the requested VDSD. In many cases, form, size, labeling, coloring, etc. did not give a clear indication of type and function of a VDSD. (For example, most brands of hand-held flares and smoke signals looked very much alike.) The problem was compounded when non-transparent packaging material was used (for example, a box) through which the VDSD could not be seen.

1.1 Coding for Identification: General

Coding is specifically applied to the shape/form, size, color, and the label of VDSD. These techniques should be combined as appropriate to achieve maximum differentiation among VDSD, and easy identification of a specified VDSD. The specific coding method to be emphasized depends on the following:

- The total demands on the operator during the time when the device must be identified.
- Speed and accuracy with which the device must be identified.
- Space on the device available for coding.
- Number of general categories of devices to be coded.
- Worst expected environment conditions.

The following human factors/ergonomic recommendations are specific guides for the coding of VDSD for the purpose of identification. In each case, the worst expected conditions under which the VDSD might have to be identified were used as the basis for the recommendations. Particularly, it was assumed that the operator was unexperienced in the selection and operation of VDSD, under severe stress and exhausted, but not injured or otherwise under severe physical impairment. The most severe environmental condition assumed is one of "darkness" (i.e., 0.01 ft. Lambert or less), which requires dark adaptation of the operator's eyes.

1.2 Form Coding for Identification

Making devices easily identified by their form decreases the number of times a wrong device is used, and reduces the time required to find the correct device.

Form can often be used to indicate the type of VDSD and to signify its handling characteristics. At present, however, form coding cannot be supported by an array of objective criteria because most form coding sterotypes are subjective and not clearly identified. Nevertheless, some coding techniques "work" even without objectively defined criteria. For instance, to most people a pistol shaped launcher indicates by its form that a projectile will be shot from this device. Therefore, it will be handled in the manner of regular hand guns. Other examples are flares or smoke signals whose shaped handle indicates that this is a hand-held device.

Form coding provides visual as well as tactile identification of VDSD. Visual form coding requires that the VDSD be seen under sufficient lighting, while tactile form coding requires that the device be grasped before recognition. Therefore, form coding should relate to the visual and tactile senses concurrently.

The following general rules shall be observed in form coding:*

- Use forms that are easily associated with, or suggest, the function of the device.
- Use forms that can be easily identified visually and that suggest by their "tactile qualities" the function and correct operation.

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* No more specific statements concerning form coding can be made presently because valid ergonomic/human factors information is simply not at hand. It is suggested that related experiments should be performed for VDSD. It is highly probable that rather simple form coding methods could evolve from such research, which would help significantly in the identification and the manipulation of VDSD.

- Use forms which are easily distinquished from each other.
- Avoid sharp edges on the part of the device which must be grasped.
- Flags or pennants should be stored in a folded flat form and not rolled up. (They should not appear like cylinders which, on first glance, could be confused with other tubular devices such as flares or smoke signals.)

Forms selected for the ease of operation (see "Operation") shall override form considerations for the ease of identification, if such conflict arises.

1.3 Size Coding for Identification

Making devices easily identified by their size decreases the number of times a wrong device is selected, and reduces the time required to find the correct device.

Size coding is intimately related to form coding. Like form, size should be an indication of the function of the device and its manipulation. VDSD can be coded by size, but if the operator must rely on touch alone, the number of usable sizes is quite limited. The ability to discriminate size by touch is relatively independent of shape discrimination. Hence, size coding can be superimposed on shape coding. Very few users would confuse, for instance, small shells to be inserted into a pistol-type launcher with smoke or flare signals to be held in the hand during operation; smoke canisters to be thrown overboard could be either too small to be hand-held, or too large; and small canisters to be thrown overboard should be sufficiently different in size from shells to be used in launchers.

Size coding, like form coding, provides visual as well as tactile indentification of VDSD. However, visual size coding requires that the device be grasped before recognized. Therefore, size coding should relate to the visual and tactile senses concurrently. The following general rules shall be observed in size coding:*

- Use sizes that are easily associated with or suggest the function of the device.
- Use sizes that can be easily identified visually and that suggest by their "tactile feel" the function and correct operation.

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*No more specific statements concerning size coding can be made presently because valid ergonomics/human factors information is simply not at hand. It is suggested that related experiments should be performed for VDSD, probably in conjunction with research into form/shape coding.

- Use sizes which are easily distinquished from each other.
- Avoid sharp edges on the part of the device which must be grasped.

Size (dimensions) selected for the ease of operation (see "Operation") should override size considerations for the ease of identification, is such conflict arises.

1.4 Color Coding for Identification

Colors should be used in accordance with population stereotypes to help in the identification of VDSD and to indicate their mode of use. Color coding is most effective when a specific meaning can be attached to the color (e.g., red for hot).

The use of color coding is dependent upon the illumination. Color discrimination is severly reduced under low illumination levels. Therefore, maximum use should be made of high contrast colors, particularly, white against black. Color should not be used as the sole or primary method of coding devices. It is particularly effective when combined with other methods.

Generally, in addition to black and white, only five colors should be used for color coding; red, orange, yellow, green, blue. They should conform with FED-STD-595, or be a CG approved equivalent. By patterning colors, such as striping, many distinctive combinations are possible.

Colors should be used as follows:

Red for flaming or hot devices, such as flares, whether hand-held or launched. If hand-held, the red color should be at that part which will be in flames or hot. (On a launcher the launching side should be colored red.)

Orange for smoke signaling devices. If hand-held, the orange coloring should be at the part which will emit the smoke.

Yellow or green (yellow-green) for cool lights. If hand-held, the color should be at that part which emits the light.

White for part(s) intended for safe and correct handling of the device. If the device is not hand-held while in function, no part should be white.

Black for background of labels. Preferably, the black surface should be located so that it separates the active part from the handle.

Combinations of colors should be used if a device or part thereof combines several functions for which colors have been designated. The colors should appear in alternating stripes.

Stripes should be of equal width of at least one centimeter.

<u>Color of flags and pennants</u> should be visable even when stored or packaged.

1.5 Labeling for Identification

The purpose of "labeling for identification" is to indicate to the user the type of specific VDSD. The label may or may not include references to its manipulation. Examples: "flag"; "flare, hand-held"; "smoke canister, floating"; "aerial flare".

While labeling can be very effective, and in many cases is necessary to verify a preliminary identification, it requires visual discrimination and sufficient illumination. Labels must always be attached to the device. Additional labeling, for instance on the packaging material, can be helpful; however, it should conform in style and contents with the labeling on the device.

1.5.1 Labeling for Identification: General

VDSD shall be appropriately and clearly labeled to permit rapid and accurate indentification. The characteristics of the labeling to be used are determined by such factors as

- the accuracy of identification required
- the time available for recognition
- the distance at which the labels must be read (assumed: 70cm viewing distance)
- the illumination level (assumed: "darkness", i.e. illumination of the label at a maximum of 0.01 ft.Lambert)

Labels should conform to these principles:

- each VDSD shall be labeled according to its function
- all labeling shall be in the simplest and most direct manner possible
- labels should give the user any needed information
- labels should be located consistently on all VDSD where they can be easily seen
- labels should use familiar words
- labels should be so printed that they read horizontally, not vertically, in regular use
- labels should be supplemented by other coding procedures, such as form, size, color.

1.5.2. Labeling for Identification: Orientation and Location

Orientation Lables shall be oriented so that they can be read quickly and easily from left to right.

Location Labels shall be placed on the items which they identify. Labels shall be located so as not to obscure any other information needed by the operator. Other items on the VDSD shall not obscure the label.

Standardization Labels shall be located in a consistent manner on all related VDSD.

1.5.3 Labeling for Identification: Contents

Label Contents Labels shall describe clearly the function of the VDSD.

Abbreviations Abbreviations and symbols shall be in accordance with USCG approved standards. Capital letters shall be used. Punctuation shall be omitted except where needed to preclude misinterpretation. The same abbreviation or symbol shall be used for all tenses and for both singular and plural forms of a word.

Brevity Labels shall be as concise as possible without distorting the intended meaning or information. They shall be unambiguous. Redundancy shall be minimized. Brevity is less important than clarity of meaning.

Familarity Words shall be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended.

Symbols Common, meaningful symbols may be used when advantageous or necessary.

Visibility and Legibility Labels shall be read easily and accurately at the anticipated operational reading distance (70cm) and illumination level (0.01ft.L.) taking into consideration primarily the following factors:

- Contrast between the lettering and its immediate background,
- Height, stroke width, spacing, and style of letters and numerals,
- Method of application (for instance, etching, decal),
- Relative legibility of alternate words.

Access Labels shall not be covered or obscured by other parts of the VDSD

Label Life Labels shall be sharp, have high contrast and be mounted to minimize wear or damage.

Label Background Label color shall contrast with the equipment background.

1.5.4 Labeling for Identification: Design of Label Characters

White Characters Characters shall be white on black background for high visibility in low level illumination. (This requirement does not apply to trade or manufacturer names, identification numbers, etc.)

Style Style of label characters should conform with military standard MIL-M-18012. Key words and short label text shall be in capital letters. Numerals should be arabic; avoid Roman numerals.

Letter Width The width of letters shall be 3/5 of the height, except for the "I" which will be one stroke in width, and the capitals "M" and "W", which shall be 4/5 of the height.

Numeral Width The width of numerals shall preferably be 3/5 of the height except for "4" which shall be one stroke width wider, and the "1" which shall be one stroke in width.

Wide Characters Where conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio of 3:5 may be increased to 1:1.

Stroke Width The stroke width shall be 1/7 to 1/8 of the height.

Character Spacing The minimum space between characters shall be one stroke width.

Line Spacing The minimum space between lines shall be 1/2 character in height.

Character Height The height of letters and numerals shall be between .4 and .75cm for reading under low level illumination.

2. UNPACKAGING

Unpackaging is the second phase in the signaling sequence. The unpackaging "instructions" tell the user how to perform the necessary "manipulations". Unpackaging procedures must be as simple and quick as possible. They should not require any specific prior experience with the type of packaging material, or with the opening procedures. Ideally, the unpackaging techniques required should be so obvious so that no written instructions are necessary.

The experiments performed with existing VDSD indicated, however, that unpackaging posed severe problems. Many subjects took unacceptably long times to open boxes, or to rip open plastic wrapping, etc. The problems encountered generally resulted from uncertainty regarding where and how to open a package, or from the lack of hand-holds which subjects could securely grasp in order to exert the force required to open the package. Plastic wrappers specifically showed the compound problem of requiring high tearing forces while offering very little surface for the fingers to grasp.

Such problems could have severe consequences if encountered under actual distress conditions in which very little time might be available for the operation of the signaling device, and in which humidity or cold might reduce operator's capability to perform complex motions involving high strength exertions.

Pull tabs, marked starter cuts, prominent opening controls, and other elements of the package commonlay perceived as "openers" should be employed. All design features, including form and size, shall ensure that even an unexperienced and weak person can unpackage the VDSD without additional tools and in minimum time under stressful conditions.

2.1 Unpackaging Instructions: General

Correct unpackaging procedures should be so obvious that extensive written instructions for unpackaging are not required. However, instructions shall be employed if they are necessary or helpful to achieve correct, safe, and rapid unpackaging.

2.1.1 Labeling for Unpackaging: General

The characteristics of labeling to be used are determined by such factors as:

- The required accuracy of the perceived information,
- The time available for unpackaging,
- The distance at which the label must be read (assumed: 70cm viewing distance),
- The illumination level (assumed: "darkness", i.e., illumination of the label a maximum of 0.01 ft.L.).

Labels should conform to these principles:

- All labeling shall be in the simplest and most direct manner possible.
- Labels should give all necessary information to the user.
- Labels should be located consistently on all packages where they can be seen easily.
- Labels should use familiar words.
- Labels should be brief but unambiguous.
- Words should be so printed that they read horizontally, not vertically, in regular use.
- Labels should be supplemented with other coding procedures such as form, size, and color.

2.1.2. Labeling for Unpackaging: Orientation and Location

Orientation Labels shall be oriented so that they can be read quickly and easily from left to right.

Location Labels shall be placed on, or close to, the items which they identify. Labels shall be located so as not to obscure any other information needed by the operator. Other items on the VDSD shall not obscure the label.

Standardization Labels shall be located in a consistent manner on all related VDSD.

Fixation Labels shall be securely attached to the package or, if feasible, to the VDSD.

2.1.3 Labeling for Unpackaging: Contents

Label Contents Labels shall describe clearly the unpackaging manipulations.

Abbrevaitions Abbreviations and symbols shall be in accordance with USCG approved standards. Capital letters shall be used. Interpunctuation shall be omitted except where needed to preclude misinterpretation. The same abbreviation or symbol shall be used for all tenses and for both singular and plural forms of a word.

Brevity Labels shall be as consise as possible without distorting the intended meaning or information. They shall be unambiguous. Redundancy shall be minimized. Brevity shall not be stressed if the results will be unfamiliar to the operator.

Familarity Words shall be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended.

Symbols Common, meaningful symbols may be used as advantageous or necessary.

Visibility and Legibility Labels shall be read easily and accurately at the anticipated operational reading distance (70cm) and illumination level (0.01 ft. L. or less) taking into consideration primarily the following factors:

- Contrast between the lettering and its immediate background,
- Height, stroke width, spacing, and style of letters and numerals,
- Method of application (for instance, etching, decal)
- Relative legibility of alternate words.

Access Labels shall not be covered or obscured by other parts of the VDSD.

Label Life Labels shall be sharp, have high contrast and be mounted to minimize wear or damage.

Label Background Label color shall contrast with the equipment background.

2.1.4 Labeling for Unpackaging: Design of Label Characters

White Characters. Characters shall be white on black background for high visibility in low level illumination.

Style. Style of label characters should conform with military standard MIL-M-18012. Key words and short label text shall be in capital letters. Extended copy (for instance, instructions) may incorporate lower case letters. Numberals should be Arabic; avoid Roman numerals.

Letter Width. The width of letters shall be 3/5 of the height, except for the "I" which will be one stroke in width, and the capitals "M" and "W", which shall be 4/5 of the height.

Numberal Width. The width of numberals shall preferably be 3/5 of the height except for "4" which shall be one stroke width wider, and the "1" which shall be one stroke in width.

Wide Characters. Where conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio of 3:5 may be increased to 1:1.

Stroke Width. The stroke width shall be 1/7 to 1/8 of the height.

Character Spacing. The minumum space between characters shall be one stroke width.

Word Spacing. The minimum space between words shall be one character.

Line Spacing. The minimum space between lines shall be 1/2 character in height.

Character Height. The height of letters and numerals shall be between .4 and .75 cm for reading under low level illumination.

2.2 Manipulations in Unpackaging

All manipulations necessary to unpackage a given VDSD shall be as simple and straightforward as possible. Major aspects affecting the correct, quick, effortless, and safe unpackaging are size and shape of the package, tear or other resistance to the opening effort. Whenever possible, starter cuts, rip bands or other "openers" should be incorporated in the package (but not separately attached).

2.2.1 Manipulations in Unpackaging: General

The design features of the package are determined by such factors as:

- The design of the VDSD itself,
- The time available for unpackaging,
- The given environmental conditions,
- Water-proofing requirements.

The package design should conform to these principles:

- Unpackaging shall require only the simplest and most familiar motions.
- Unpackaging shall require only a minimum of muscular strength and skill.
- "Openers" shall be incorporated in all packages as far as feasible.
- Unpackaging procedures shall be designed for an untrained and unskilled operator.
- The manipulations required in the unpackaging should necessitate the use of only one hand.
- Tools shall not be required for the unpackaging.

2.2.2 Manipulations in Unpackaging: Form and Size

Form and size should be conducive for quick and easy unpackaging. The form of the packaging material, or elements thereof, should be shaped for easy visual and tactile recognition of where and how to open the package. Incorporated "openers", such as starter cuts, pull tabs, latches, snaps, buttons, shall be used where practical. The form of the opener shall attract the operator's attention and indicate unambiguously the kind of action required.

2.2.3 Manipulations in Unpackaging: Size, Shape, and Strength Required

Sizes and shapes of the package and its opener shall be conducive to correct, quick and effortless unpackaging.

During unpackaging, the VDSD may be held and manipulated in many different ways. However, configurations of the hand on the package can be reduced to five basic grips between fingers and material:

A) Thumb-Finger Palmar Grip
B) Thumb-Fingertip Enclosure
C) Power Grip
D) Thumb-Forefinger Side Grip
E) One-Finger Touch

These grips are shown in Figure A1.

There are close interactions between the grips used in unpackaging, and the dimensions of the package, including its openers. For each of the five grips shown in Figure A1, Table A1 lists recommended dimensions.

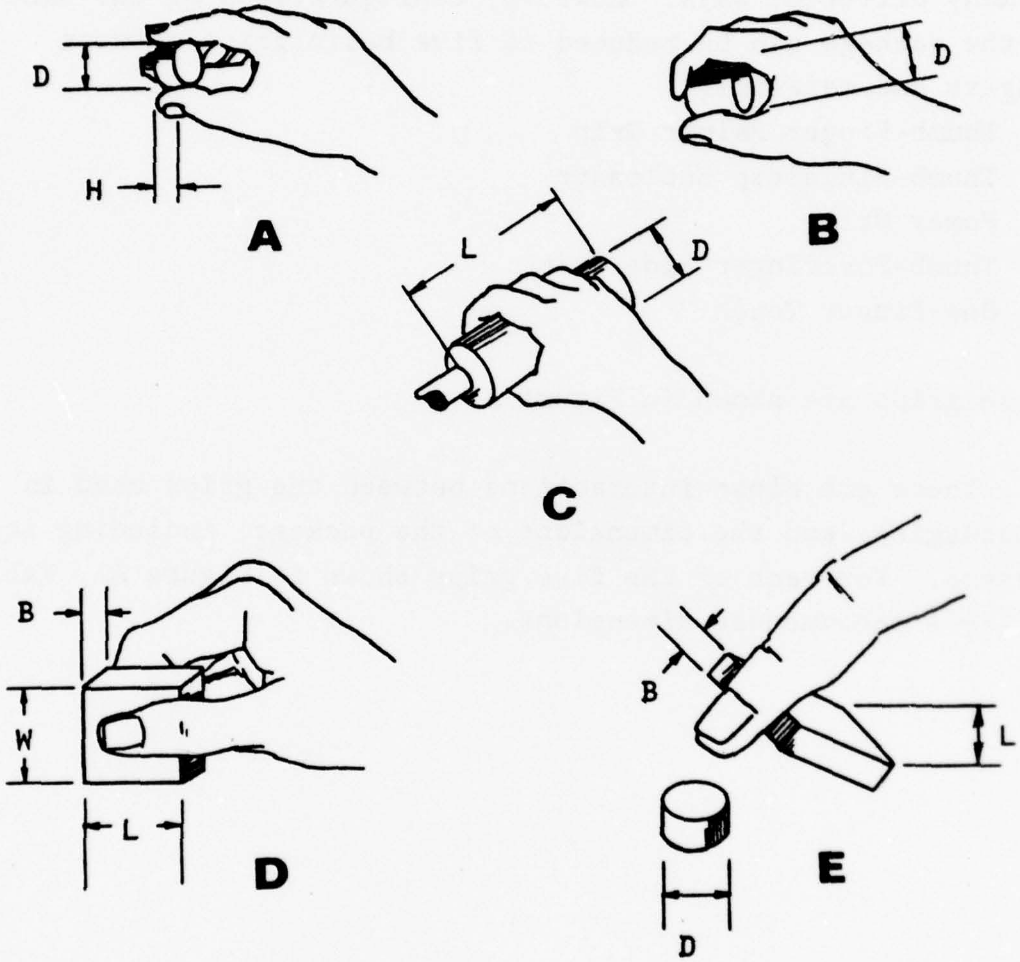

Figure A1: Five Basic Grips (adapted from Roebuck, Kroemer, Thomson 1975, and MIL-HDBK-759, 12 March, 1975.)

	Grip A			Grip B			Grip C			Grip D				Grip E			
	H cm	D cm	F N	H cm	D cm	F N	D cm	L cm	F N	B cm	W cm	L cm	F N	D cm	B cm	L cm	F N
Minimum	1.25	1	?	1.25	2.5	?	3.8	7.5	?	-	1	1	-	1	1	1	-
Maximum	2.5	10	?	2.5	7.5	?	7.5	-	?	1	-	-	35	2.5*	2.5*	2.5*	12

?: No data available.

*: Estimate

Table A1: Recommended Dimensions and Strength Requirements (in Newton) for Unpackaging VDSD (Adapted from MIL-HDBK-759, 12 March, 1975, and Van Cott and Kinkade, 1972)

3. OPERATION

All procedures needed in the operation of a VDSD shall be as simple and quick as possible. They shall not require from the operator any prior experience with the type of the device, or with the specific operating procedures. Ideally, the operation techniques required should be so obvious that no written instructions are necessary.

Many of the VDSD investigated showed a number of deficiencies with respect to ease, speed, and safety of operation. Subjects found it difficult to understand or follow the instructions given for the operation, either because the instructions were difficult to decipher or because the wording of the instructions was not clear to them. In some cases the shape of the device itself was unsatisfactory, or the "trigger" was difficult to operate.

Tabs, knobs, pull rings, triggers, and other elements commonly perceived as "starters" or "triggers" shall be employed. All design features, including overall form and sizes, shall ensure that even an unexperienced and weak person can operate the VDSD without additional tools and in a minimum of time under stressful conditions.

For correct, quick, and safe operation, two features of VDSD must be optimized: the labeled instructions which tell the user how to operate the VDSD, and the related design features of the VDSD itself.

3.1 Operation Instructions: General

Correct operation procedures should be so obvious that extensive written instructions for operation are not required. However, instructions shall be employed if they are necessary or helpful to achieve correct, safe and rapid operation.

The labeling for operation can often be combined with, and usually follows, the labeling for identification.

3.1.1 Labeling for Operation: General

VDSD shall be appropriately and clearly labeling to permit rapid and accurate operation. The characteristics of the labeling to be used are determined by such factors as:

- The accuracy of identification required,
- The time available for operation,
- The distance at which the labels must be read (assumed: 70cm viewing distance),
- The illumination level (assumed: "darkness", i.e., illumination of the label at a maximum of 0.01 ft.L.),

Labels should conform to these principles:

- All labeling shall be in the simplest and most direct manner possible.
- Labels should give all necessary information to the user.
- Labels should be located consistently on all VDSD where they can be easily seen.
- Labels should use familiar words.
- Labels should be brief but unambiguous.
- Words should be so printed that they read horizontally, not vertically, in regular use.
- Labels should be supplemented with other coding procedures, such as form, size, and color.

3.1.2 Labeling for Operation: Orientation and Location

Orientation. Labels shall be oriented so that they can be read quickly and easily from left to right.

Location. Labels shall be placed on the items which they identify. Labels shall be located so as not to obscure any other information needed by the operator. Other items on the VDSD shall not obscure the label.

Standardization. Labels shall be located in a consistent manner on all related VDSD.

3.1.3 Labeling for Operation: Contents

Label Contents. Labels shall describe clearly the operating manipulations.

Abbreviations. Abbreviations and symbols shall be in accordance with USCG approved standards. Capital letters shall be used. Interpunctuation shall be omitted except where needed to preclude misinterpretation. The same abbreviation or symbol shall be used for all tenses and for both sigular and plural forms of a word.

Brevity. Labels shall be as concise as possible without distorting the intended meaning or information. They shall be unambiguous. Redundancy shall be minimized. Brevity shall not be stressed if the results will be unfamiliar to the operator.

Familiarity. Words shall be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended.

Symbols. Common, meaningful symbols may be used as advantageous or necessary.

Visibility and Legibility. Labels shall be read easily and accurately at the anticipated operational reading distance (70cm) and illumination level (0.01 ft.L. or less), taking into consideration primarily the following factors:

- Contrast between the lettering and its immediate background,
- Height, stroke width, spacing, and style of letters and numerals,
- Method of application (for instance, etching, decal),
- Relative legibility of alternate words.

Access. Labels shall not be covered or obscured by other parts of the VDSD.

Label Life. Labels shall be sharp, have high contrast and be mounted to minimize wear and damage.

Label Background. Label color shall contrast with the equipment background.

3.1.4 Labeling for Operation: Design of Label Characters

White Characters. Characters shall be white on black background for high visibility in low level illumination.
Style. Style of label characters should conform with military standard MIL-M-18012. Key words and short label text shall be in capital letters. Extended copy (for instance, instructions) may incorporate lower case letter. Numerals should be Arabic; avoid Roman numerals.
Letter Width. The width of letters shall be 3/5 of the height, except for the "I" which will be one stroke in width, and the capitals "M" and "W", which shall be 4/5 of the height.
Numeral Width. The width of numerals shall preferably be 3/5 of the height except for "4" which shall be one stroke width wider, and the "1" which shall be one stroke in width.
Wide Characters. When conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio of 3:5 may be increased to 1:1.
Stroke Width. The stroke width shall be 1/7 to 1/8 of the height.
Character Spacing. The minimum space between characters shall be one stroke width.
Word Spacing. The minimum space between words shall be one character.
Line Spacing. The minimum space between lines shall be 1/2 character in height.
Character Height. The height of letters and numerals shall be between .4 and .75 cm for reading under low level illumination.

3.2 Manipulations in Operation

All manipulations necessary to operate a given VDSD shall be as simple and straightforward as possible. Major aspects affecting the correct, quick, effortless, and safe operation are form, size, shape, color of the device, and of its parts or elements that must be manipulated.

3.2.1 Manipulations in Operation: General

The design features of the VDSD are determined by such factors as:

- The type of the VDSD operation,
- The time available for operation,
- The given environmental conditions,
- Water-proofing requirements.

The design of the VDSD should conform to these principles:

- Operation shall require only the simplest and most familiar motions.
- Operation shall require only a minimum of muscular strength and skill.
- Starters shall be used consistently with all VDSD as far as feasible.
- Operating procedures shall be designed for an untrained and unskilled operator.
- The manipulations required in the operation should necessitate the use of only one hand.
- Tools shall not be required for the operation.

3.2.2 Operating Manipulations: Form and Size

Form and size should be conducive for quick and easy operation. The form of the VDSD itself, and its elements, should be shaped for easy visual and tactile recognition of where and how to operate the device. "Starters" such as tabs, latches, snaps, buttons, and triggers, shall be used as appropriate. Their form shall attract the operator's attention and indicate unambiguously the kind of action required.

3.2.3 Operating Manipulations: Size, Shape and Strength Required

Size and shape of the VDSD and its starter elements shall be conducive to correct, quick and effortless operation.

During operation, the VDSD may be held and manipulated in many different ways. However, configurations of the hand on the VDSD can be reduced to three types of grips:

A) Thumb-Finger Palmar Grip

B) Thumb-Fingertip Enclosure

C) Power Grip

These grips are shown in Figure A2.

There are close interactions between the grips used in operating VDSD, and the dimensions of the device, including its starters or triggers. For each of the three grips shown in Figure A2, Table A2 lists recommended dimensions and force requirements.

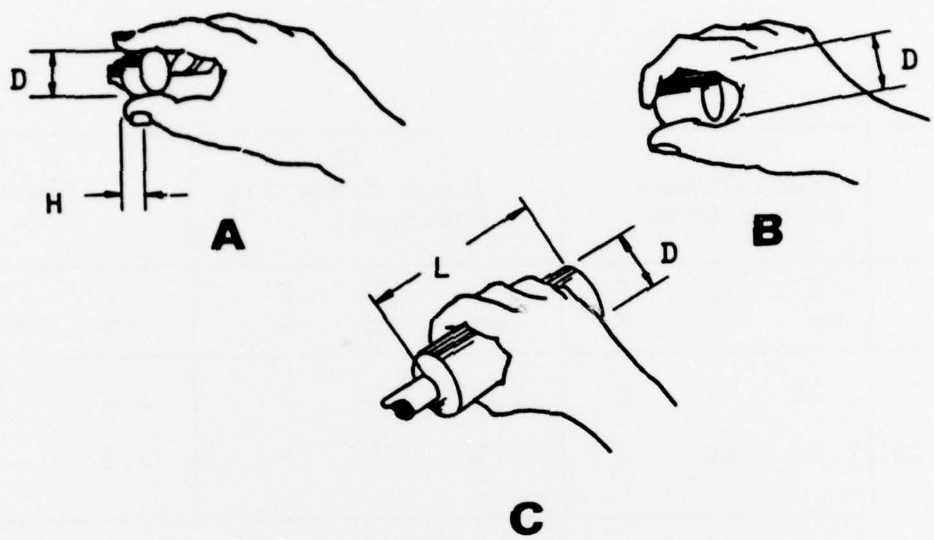

Figure A2: Three Basic grips used in operation of VDSD (adapted from Roebuck, Kroemer, Thomson 1975; MIL-HDBK-759, 12 March, 1975.)

	(A) Thumb-Finger Palmar Grip			(B) Thumb-Fingertip Enclosure			(C) Power Grip		
	H cm	D cm	F N	H cm	D cm	F N	D cm	L cm	F N
MINIMUM	1.25	1	?	1.25	2.5	?	3.8	7.5	?
MAXIMUM	2.5	10	?	2.5	7.5	?	7.5	-	35

?: No data available.

Table A2: Recommended Dimensions and Strength Requirements (F in Newton) for Operating VDSD (Adapted from MIL-HDBK-759, 12 March 1975, and Van Cott and Kinkade, 1972)

If flames, heat, slag, etc. develop at any side or end of the VDSD which could hurt the hand, grips (A) and (B) generally cannot be used; length L for grip (C) must be at least 10cm. If the device does not require more force in its operation than just necessary to be held in the hand, the minimum diameter D in case (C) can be reduced to about 1cm.

3.2.4 Manipulations in Operation: Use of Colors

Colors should be used in accordance with population stereotypes to indicate their mode of use. Color coding is most effective when a specific meaning can be attached to the color (e.g., red for hot).

The use of color coding is dependent upon illumination. Color discrimination is severly reduced under low illumination levels. Therefore, maximum use should be made of high contrast colors, particularly, white against black. Color should not be used as the sole or primary method for coding devices. It is particularly effective when combined with other methods.

Generally, in addition to black and white only five colors should be used for color coding: red, orange, yellow, green, and blue. They should conform with FED-STD-595, or be a CG approved equivalent. By patterning colors, such as striping, many distinctive combinations are possible. Colors should be used as follows:

Red for flaming or hot parts, such as on flares, whether hand-held or launched. If hand-held, the red color should be at that part which will be in flames or hot. On a launcher, the launching side should be colored red.

Orange for smoke signaling devices. If hand-held, the color should be at that part which will emit the smoke.

Yellow or green (yellow-green) for cool lights. If hand-held, the color should be at that part which emits the light.

White for the part(s) intended for safe and correct handling of the device. If the device is not hand-held while in function, no part should be white.

Black for background of labels. Preferably, the black surface should be located so that it separates the active part from the handle.

Combinations of colors should be used of a device or part thereof combines several functions for which colors have been designated. The colors should appear in alternating stripes. Stripes should be of equal width of at least one centimeter.

Color of flags and pennants should be visable even when stored or packaged.